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Finite Element Modeling of Army Airbeam Structures

May 4, 2005

JOCOTAS – Port Hueneme, CA

U.S. Army RDECOM - Natick Soldier Center Collective Protection Directorate, Fabric Structures Team

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Agenda

- Brief Overview of Airbeams
- Engineering Process
- Modeling Approaches
- Fabric Airbeam Models
- Modeling Technical Barrier
- Cavity Filled Membrane Models
- Airbeam and Fabric Membrane Models
- Application of Modeling
- Center of Excellence
- Current Small Business Innovative Research Projects

Brief Overview of Airbeams

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- Load Bearing Pressurized Fabric Structures
- Pressurization pre-tensions the fibers, creating a structure that is rigid under design loads, but deflects without damage when overloaded
- Outstanding strength-to-weight ratio

Engineering Process

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Textiles

New High Strength Seamless Manufacturing Technology

Modeling

Establish and Verify Analytical Techniques

Airbeams

Rapid Deployment
Reduced Manpower
Lightweight

Mechanical Systems

Rapid Inflation
Integral Power/ECU

System Issues

Textile/Hardware Interfaces
Deployment Technique
Airbeam/skin integration
Anchoring techniques

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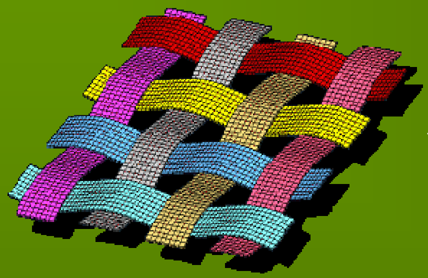
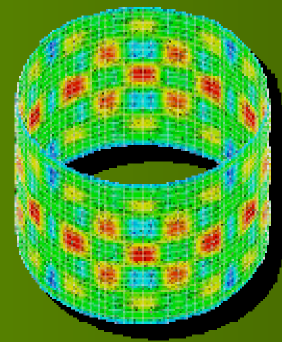
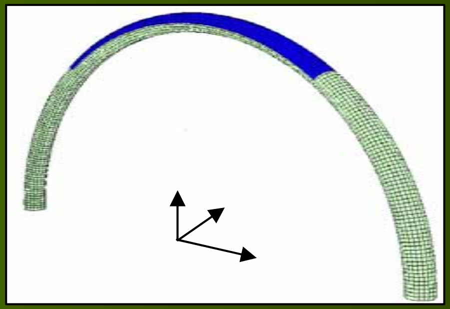
Modeling Approaches

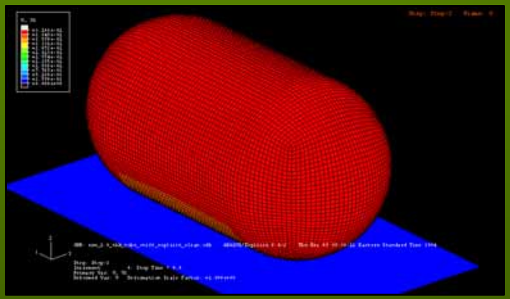
Airbeam Fabric



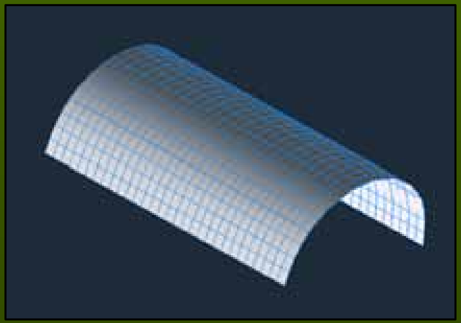




Cavity Filled Membrane



Airbeam & Fabric Membrane



Fabric Airbeam Models

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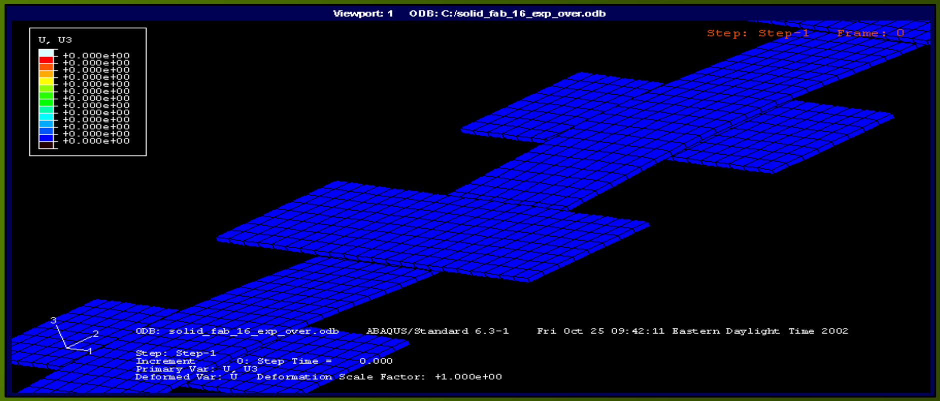
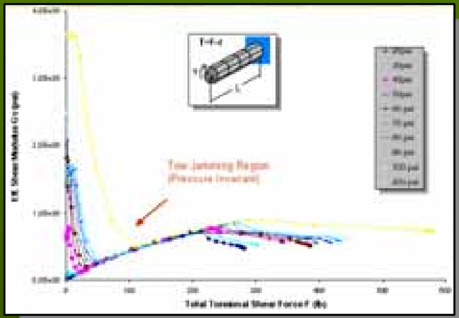
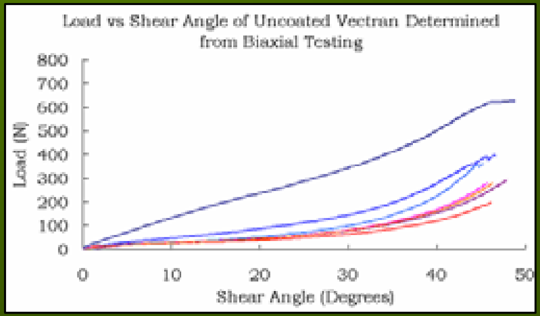




Finite Element Results
for Shear



Experimental Results
for Shear

NAVSEA NEWPORT Undersea Warfare Center Division

UMASS

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Modeling Technical Barrier

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Barrier:

Test method to evaluate structural properties of fabrics subjected to combined multi-axial tension and shear loads for design purposes

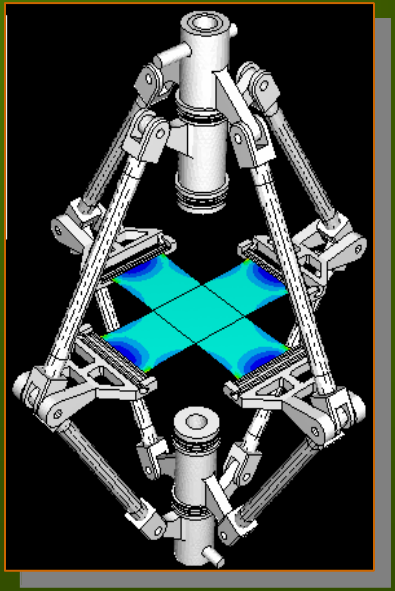
Problem:

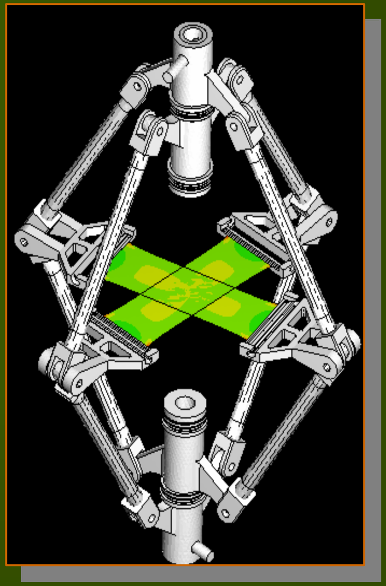
Fabric elastic modulus & shear stiffness are dependent on:

- ✓ Fiber Directions
- ✓ Fabric Construction
- ✓ Tow Density Ratios (TDR)
- ✓ Coatings
- ✓ Inflation Pressure
- ✓ Structural Loads

Solution:

A new test apprentice that can determine the pressure dependent elastic modulus and pressure dependent shear modulus.





Patent Awarded

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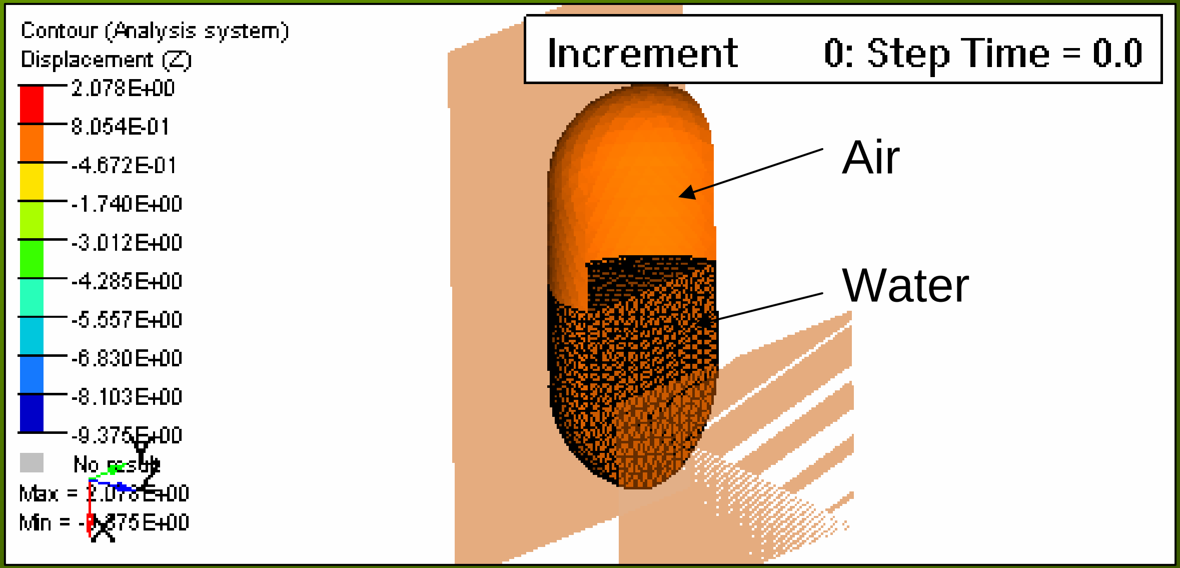
Cavity Filled Membrane Models



- Model results based on changes in cavity volume and inflation pressure
- Has begun to be explored and is in process of validation

Airbeam and Fabric Membrane Models

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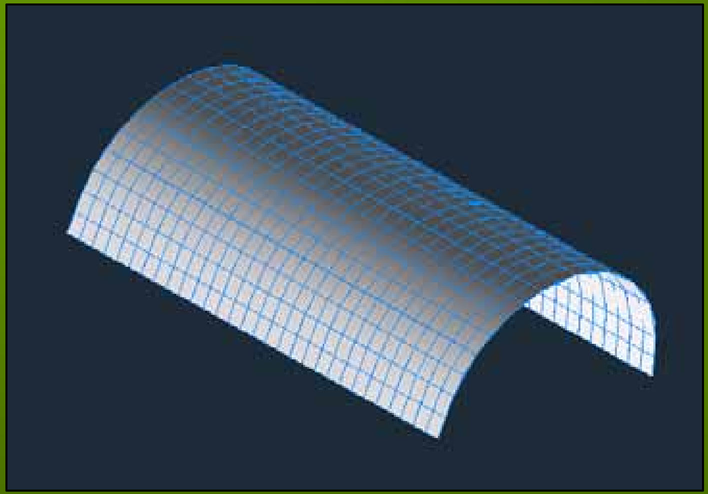

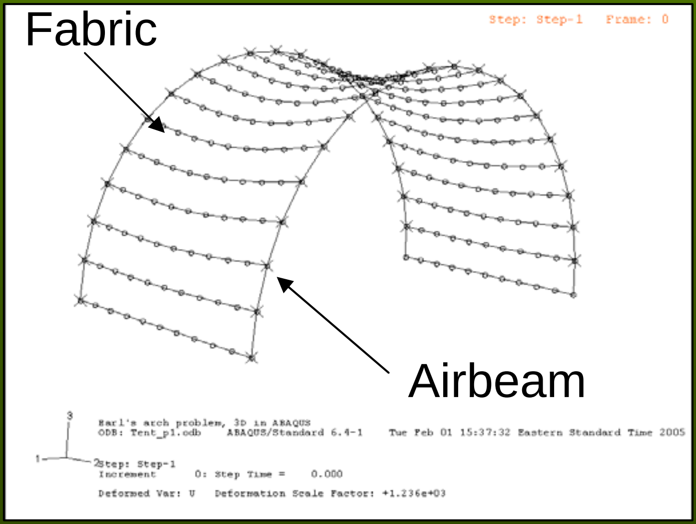

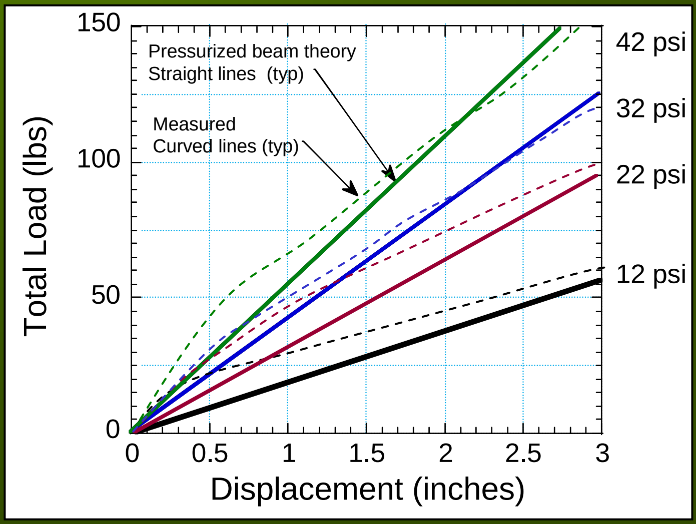

Application of Modeling

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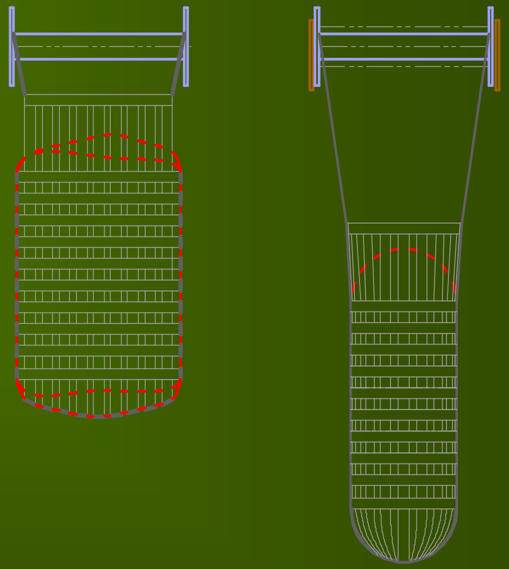
Deployable Airbeam Fender System for the Joint High Speed Connector



Deflated Inflated

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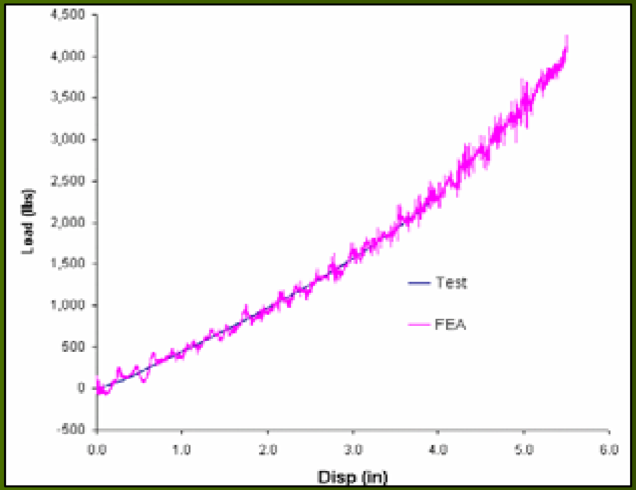
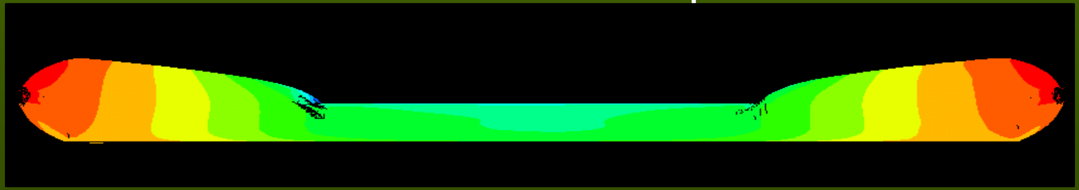
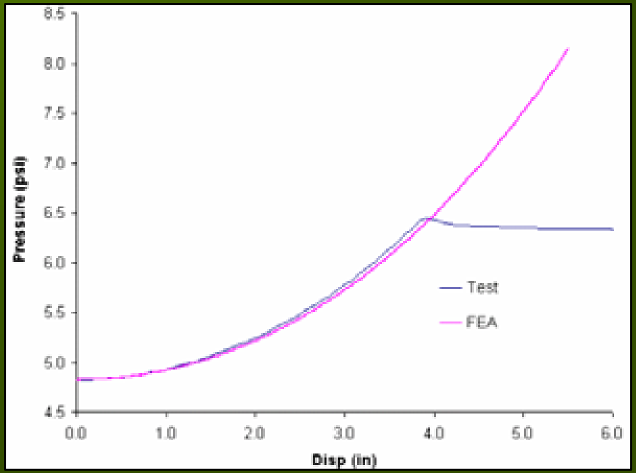
Verification of Model



Side View ~ 50% Compression





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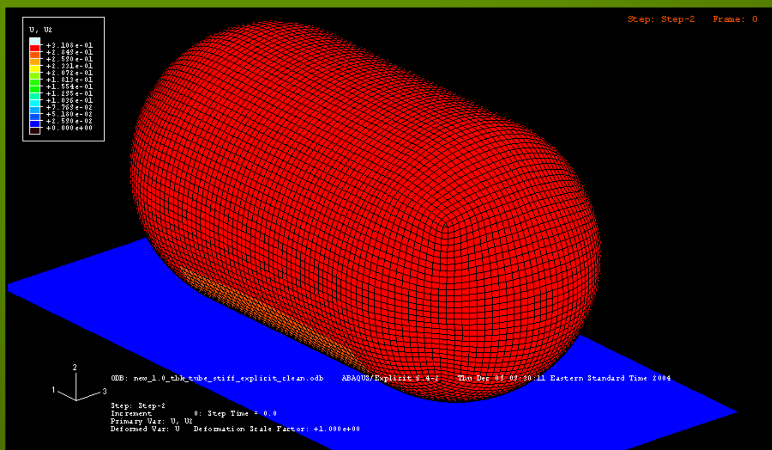
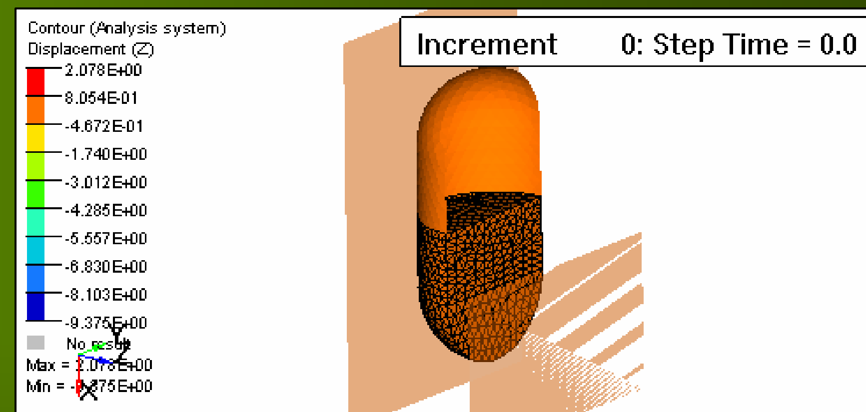
Model Variations

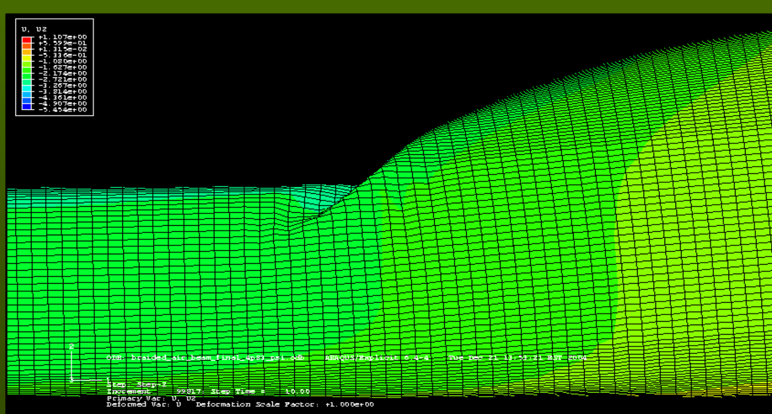
Scaled Prototype Model



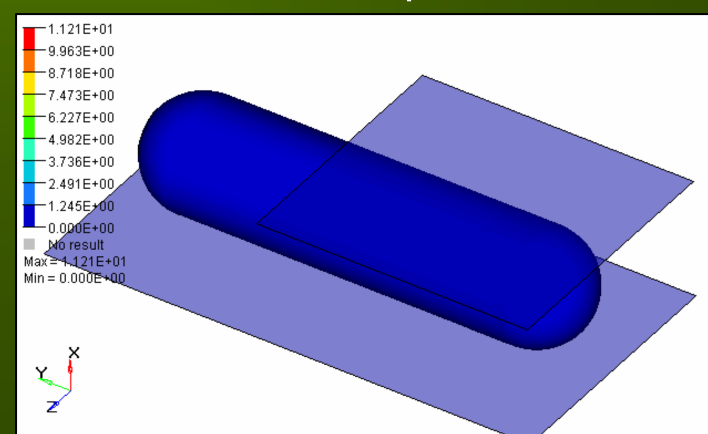
Partial Air and Water Model



Side View of Pinch Point



Partial Compression



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Increase durability, reliability and affordability

Establish predictive design tools and models

Market and Document Technology

Partner with DoD and government agencies, industry, and academia

Broaden inflatable structure applications and commercialize the technology

Vision

Deliver new inflatable technology into the hands of warfighters and commercial users.

(Established in 2001 at the Natick Soldier Center in Natick, MA)

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Small Business Innovative Research Project

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- Flexible Display
  - Physical Optics Corporation
- Solid State Lighting
  - Space Hardware Optimization Technology
  - Physical Optics Corporation
- Photovoltaic Power Shade
  - Iowa Thin Film Technologies
- Insulation
  - Aspen Aerogels
  - L'Garde, Inc.

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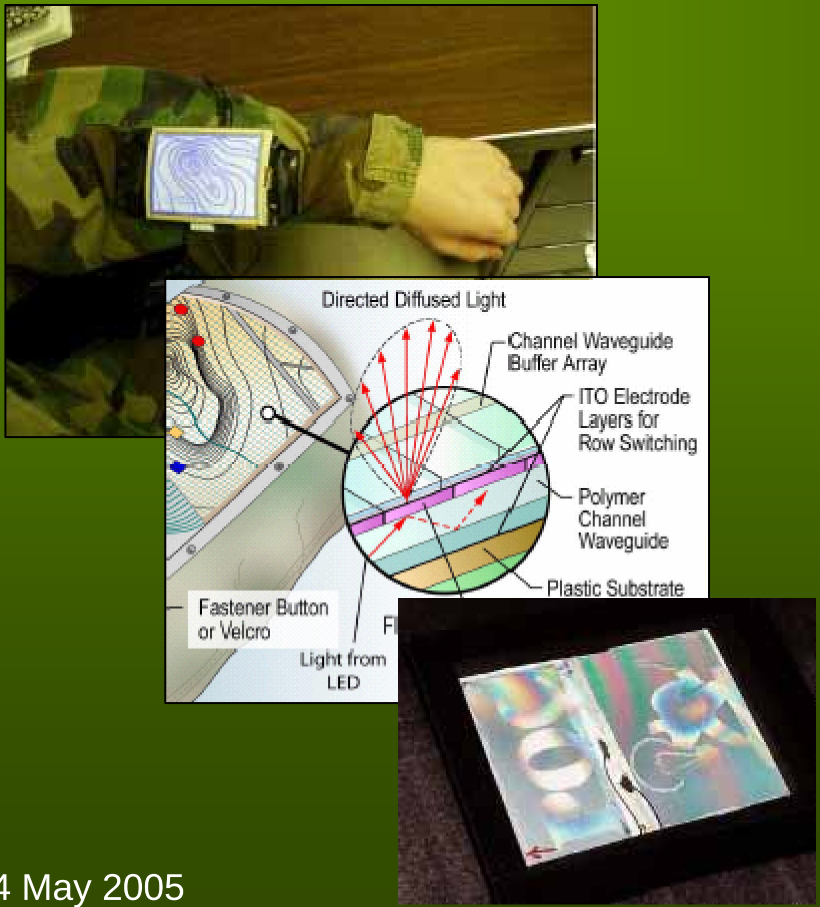
Flexible Display

POC Physical Optics Corporation



Capabilities:

- Ultra thin (<1 mm), flexible (6-10 cm bending radius), high-resolution (100 μm pixel size, total up to 640 x 480 pixels)
- Lightweight (<0.5 g per 1 cm^2 of display area, <100 g for electronics
- Full-color, real-time (30-60 Hz refresh), high-optical-contrast (>100:1) display
- Scalability in the display area (from 1 cm^2 to 1 m^2 active area)
- Visual images, such as maps and drawings, will be displayed on shelter fabric

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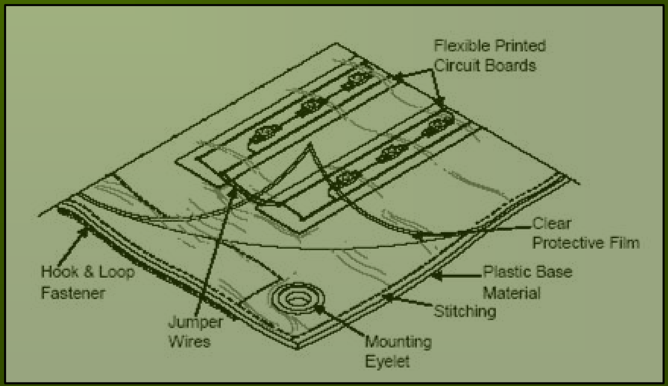
Solid State Lighting

Capabilities

- Evenly illuminates floor level (one fixture for 1 m^2) 3 m^2 in near future
- Permanently attached to shelter (deployed together)
- Operates from outside power or from battery 100,000 hr. lifetime
- Runs 6 hr. on 5 AA batteries with power shutoff
- 10 times longer life than fluorescent light
- Compact, lightweight (100 g fixture)
- All light is directed to the floor (no dispersed light)
- Solar spectrum
- Low cost in mass production ($5/fixture)


SOSIL Luminaire

POC *Physical Optics Corporation*



SHOT

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Photovoltaic Power Shade

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"Power Shade"

Application:

- Solar shade w/ integral PV power
- Provides 1 Kw of PV power, reduces solar load 80% – 90%
- Design to fit over: MGPTS small, 16' TEMPER
- Modular expandability

Dimensions: 22' x 20' x 10'9"- 14'6"

Power: ~1 **Kw**

Operating Voltage: 12V

BOS required

PV combiner boxes
Master disconnect switch
Charge controllers
12V Deep cycle batteries
Inverter for 120 VAC use

IOWA THIN FILM TECHNOLOGIES

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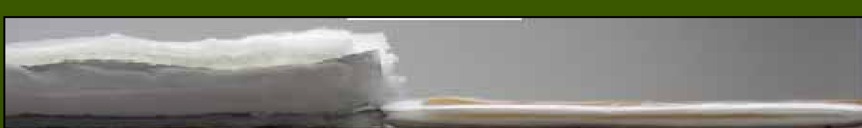
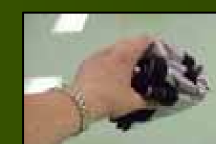
Insulation

- Aspen Aerogels
  - 85% Packing Cube Reduction
  - R-value > 6 °F·ft^2·hr/Btu
  - Flame Resistance
  - 99% Open Porosity
  - Noise and IR Suppression
  - Phase II partner with Johnson Outdoors



MIL-C-44154B Aspen Insulation

- L'Garde
  - Phase III
  - R-value > 6 °F·ft^2·hr/Btu
  - Weight < 20 oz/yd^2
  - Demonstrated 65% reduction in heating/cooling power requirements
  - Automated fabrication
  - Adjustable to fit multiple shelter geometries



Thank You